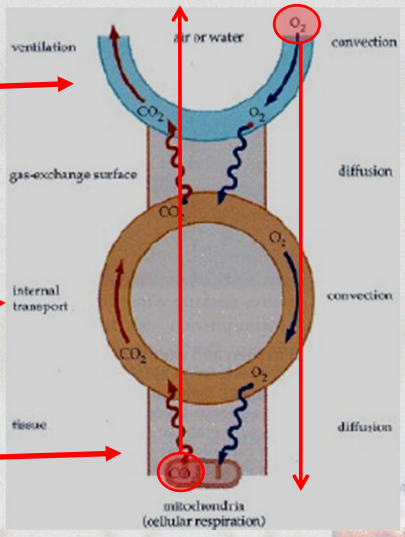
Circulatory systems

Respiration
(gas exchange) = Ventilation Convection

Pulmonary uptake
Diffusion

Circulation
Convection

Tissue exchange
Diffusion



1

Circulatory systems - function

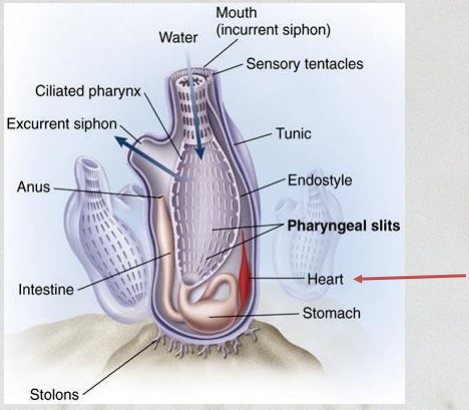
- Respiratory gas transport
- Heat transport
- Nutrient and waste transport
- Hormone transport
- Leucocyte WBC transport
- Hydrostatic skeletons
- Communication/Protection

Convection:
'carriage by fluid'

2

Unusual circulatory pattern

"ebb and flow" - ascidians - Every few minutes the heart stops beating and then restarts, pumping fluid in the reverse direction.



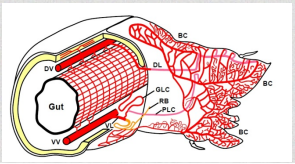
3

Invertebrate circulatory systems

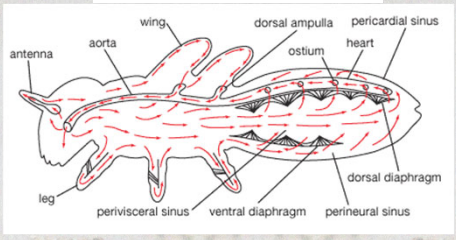
One-way flow

Heart(s), arteries, veins (lots of accessory hearts)

Open or Closed Systems: capillaries vs sinuses



Closed e.g. annelids

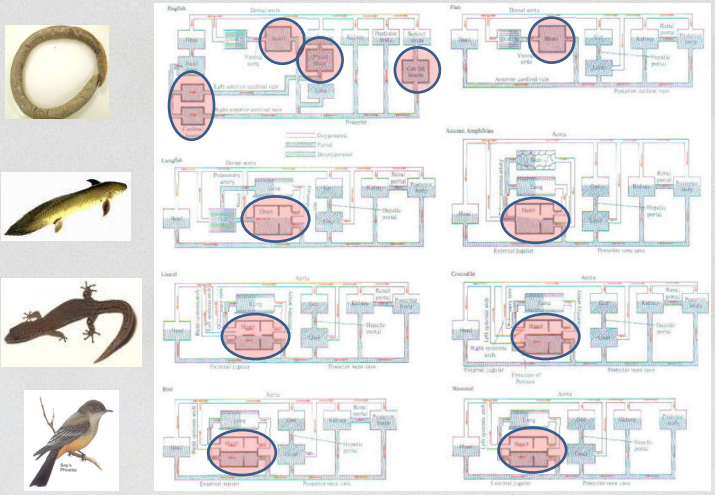


Open e.g. insects
- Large blood volume (hemolymph)
- Slow motion
- Low pressure

4

Vertebrate circulatory patterns

"pumps" and "plumbing"

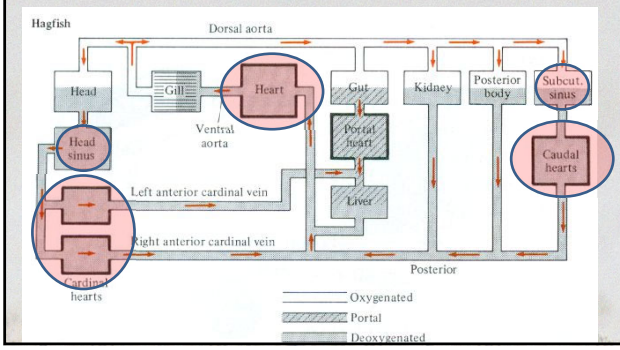


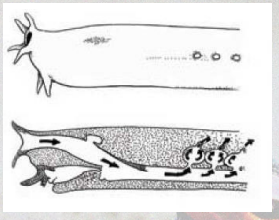
5

Hagfishes

The hagfish circulatory system is "primitive":

- partially "open" with sinuses
- the branchial heart (atrium and ventricle) pumps blood to the gill baskets then the systemic circulation



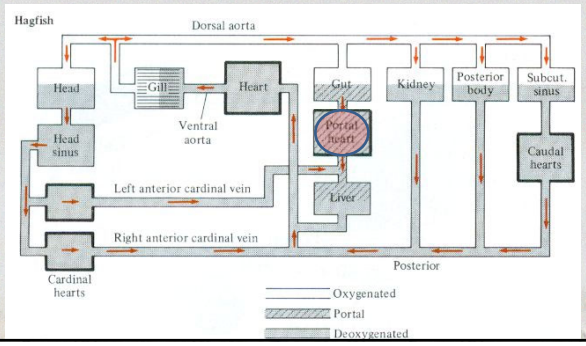


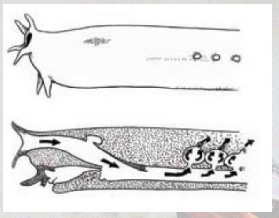
6

HAGFISHES

The hagfish circulatory system is “primitive”:

- One portal system, the hepatic portal which has a portal heart to assist flow (no renal portal system)
- Cardinal hearts

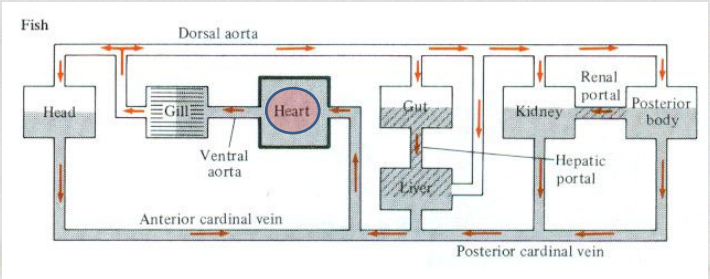




7

Elasmobranch and teleost circulation

- "closed", with no open sinuses
- the branchial heart (atrium and ventricle) pumps blood to the gill arches then the systemic circulation
- single circuit
- 2 renal portals

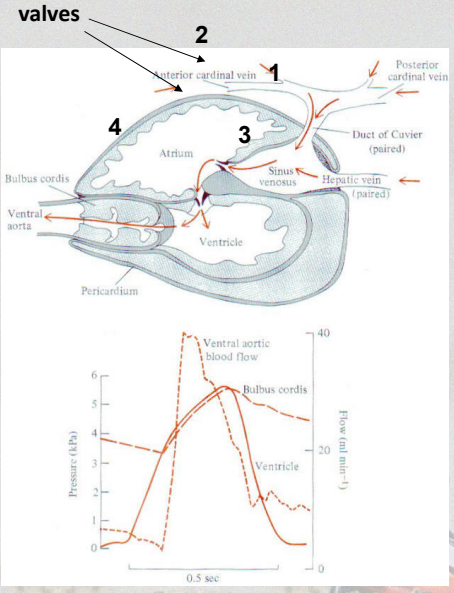


8

Elasmobranch and teleost hearts

The “4-chambered” heart has a thick ventricular muscle wall to pump blood through the gills then body

Ventricular/aortic pressures are relatively high (5 kPa)

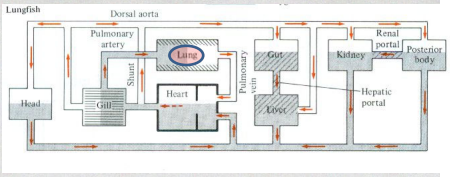


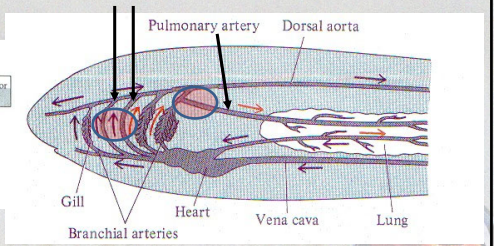
9

Lungfish

The lungfish circulatory system is more complex because of the lungs

- a branch of the most posterior aortic arch provides blood flow to the lungs
- the second and third arches lack gills, and function as a direct supply of oxygenated blood from the lungs to the body



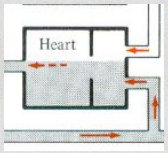


10

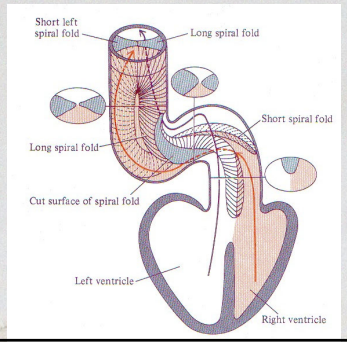
Lungfish

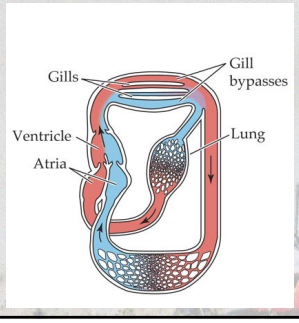
This requires separation of oxygenated pulmonary blood and deoxygenated systemic venous blood in the heart

- atrium partially divided, to separate these blood streams
- ventricle is partially divided by a fold, to separate these streams
- there is also partial functional separation of oxygenated and deoxygenated blood through the bulbus cordis by the spiral fold



Lung circulation can be shut off

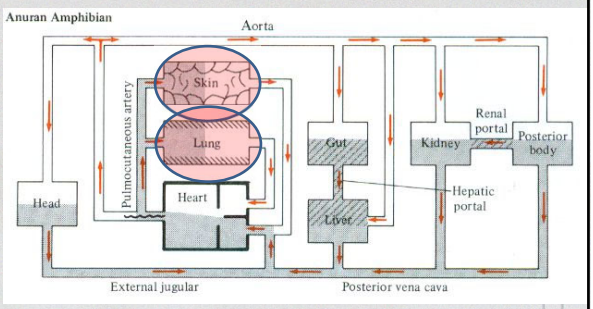




11

Amphibians

The amphibian circulatory system is also complex because of the potential use of lungs and skin (and sometimes gills), as gas exchange organs



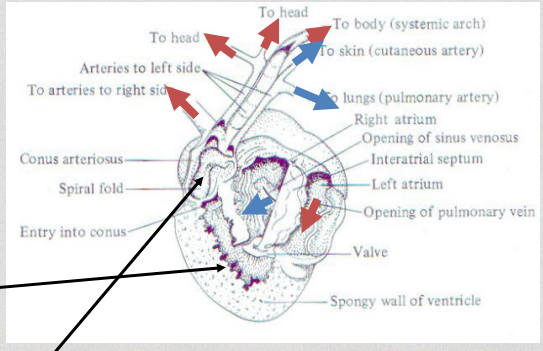
12

Amphibian hearts

the atria are completely divided to separate oxygenated and deoxygenated blood streams

the ventricle is partially (functionally) divided to separate oxygenated and deoxygenated blood streams, not by a septum but by dense trabeculation of the spongy myocardium

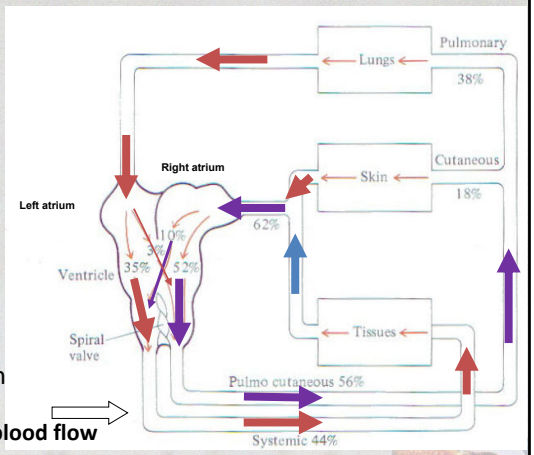
a spiral fold in the short conus arteriosus separates oxygenated and deoxygenated outflow from the ventricle



13

Amphibian hearts

- oxygenated blood from the lungs returns to the left atrium, passes through the partially divided ventricle, and is functionally kept fairly separate from the deoxygenated blood stream
- skin mixes with deoxygenated blood from the body!
- deoxygenated blood from the body returns to the right atrium, passes through the partially divided ventricle, and is functionally kept fairly separate from the oxygenated blood stream



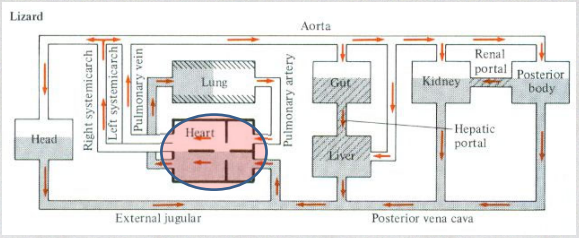
Distribution of total blood flow

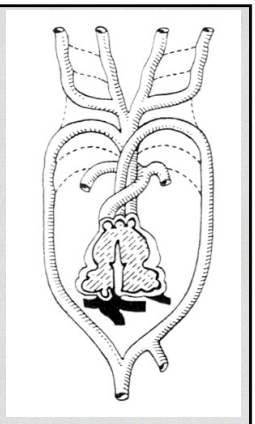
14

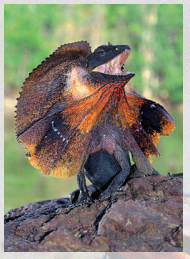
Reptiles (squamates)

The squamate (lizards, snakes) circulatory system is simplified by there being only lungs for gas exchange, but the ventricle is more complex

Good functional separation







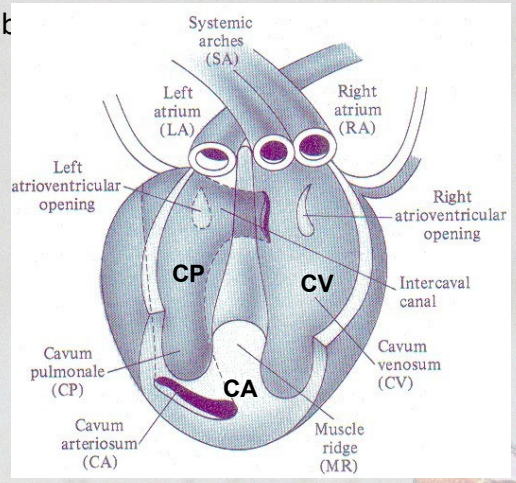
15

Reptiles (squamates)

the atria are completely divided

the ventricle is functionally b
(3) chambers

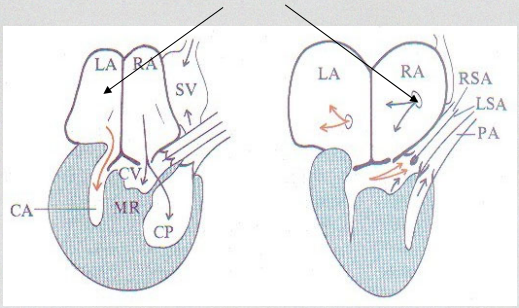
- CV: cavum venosum
- CA: cavum arteriosum
- CP: cavum pulmonale



16

Reptile hearts

- the atria are completely divided
- the ventricle is functionally but incompletely divided into three chambers (CA, CV, CP)
- good functional (but not anatomical) separation of oxygenated and deoxygenated blood - maintained by a complex pattern of flows through the three chambers.



CA cavum arteriosum
CV cavum venosum
CP cavum pulmonale

Atrial contraction
(ventricular diastole)

Ventricular contraction
(ventricular systole)

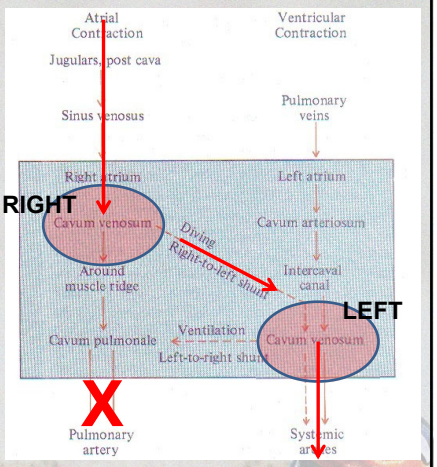
17

Reptile hearts

Complete separation (even if it were anatomically possible) would remove an advantage of incomplete, functional separation

Squamates can bypass the lungs if they want to:

RIGHT-TO-LEFT cardiac shunt during diving



18

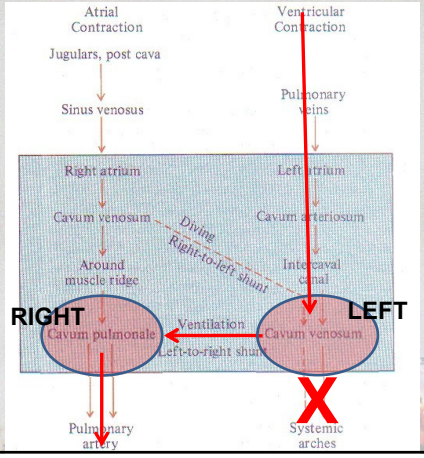
Reptile hearts

Complete separation (even if it were anatomically possible) would remove an advantage of incomplete, functional separation

Squamates can bypass the body if they want to:

LEFT-TO-RIGHT during ventilation.

Shunts are not necessarily complete

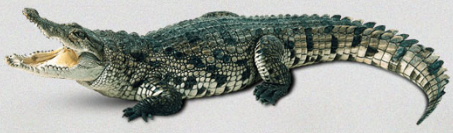


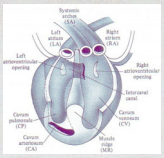
19

Evolutionary dead-end

hard to see how you could evolve this into an anatomically-divided two-chambered ventricle (crocodile, bird or mammal)!

???

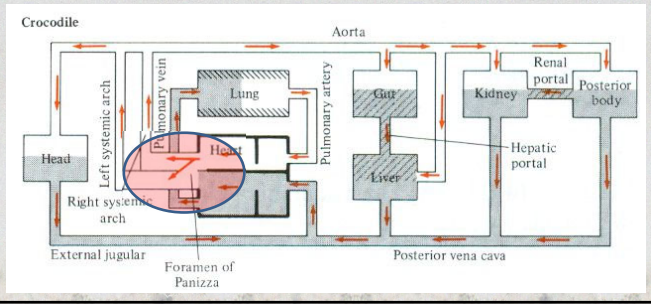




20

REPTILES (Crocodylians)

The crocodilian circulatory system is also complex, but because of complete separation of the ventricle and extra-cardiac connections.



21

Crocodylians

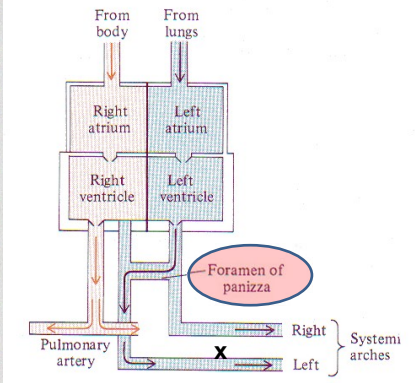
the atria and ventricles completely divided

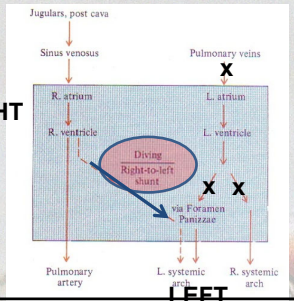
there are two systemic arches (SA) that deliver blood to the body;

Left SA arises from the right ventricle (contains deoxygenated blood) !

to have the left SA deliver oxygenated blood to the body, an extra-cardiac shunt (Foramen of Panizza) is needed.

Allowes right to left shunt like squamates!





RIGHT

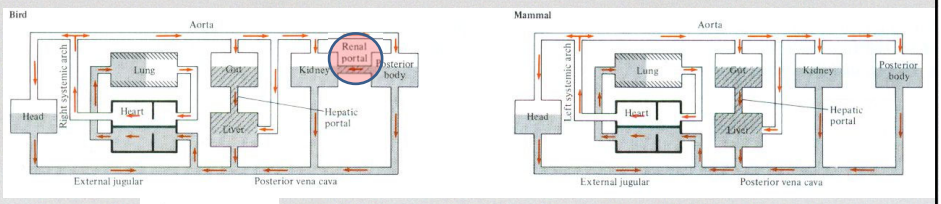
LEFT

22

Mammals and birds

The mammalian and avian circulatory systems are relatively "simple", because of the complete separation of atria, ventricles and oxy/deoxy blood streams.

Mammals have lost the nearly ubiquitous renal portal system (birds retain it).



23

Mammals and birds

Complete separation is anatomically achieved in the heart.

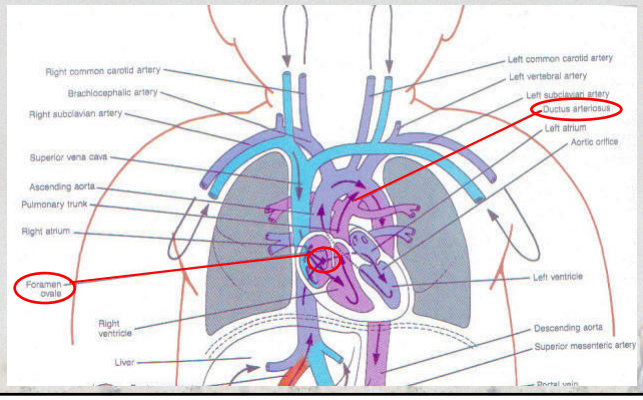
No possibility of bypassing the lungs even if you want to

- e.g. no RIGHT-TO-LEFT shunt during diving)
- but mammals and birds have such a high metabolic rate they can't survive extended anaerobiosis anyway.

24

Embryonic mammals and birds

During development there is a functional bypassing of the lungs by shunts

intracardiac (foramen ovale): RA → LA

extra-cardiac (ductus arteriosus): PA → Aorta